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South Carolina Agricultural Experiment Station

—OF—

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A Preliminary Report on the Blast of Rice

WITH NOTES ON OTHER RICE DISEASES

In Co-operation with U. S. Department of Agriculture

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Dr. H. Metcalf resigned his position as Botanist and Bacteriologist, December, 1905, and was succeeded by Prof. H. D. House.

SUMMARY.

1. Rice blast is a disease characterized by definite lesions at one or more joints of the stalk, above which the plant is killed. The disease may appear at any stage after the rice is in barrel; and hence causes varying degrees of damage.

2. Rice blast has probably been in South Carolina for thirty years at least. Within the past ten years it has caused enormous loss. It is now present on irrigated rice on every river, and widely distributed throughout the State on upland rice. It is also present in North Carolina and Texas.

3. The disease is readily produced by inoculating healthy plants directly from diseased plants; but so far has not been produced by pure cultures of any one organism.

4. Rice blast occurs in its most virulent form, and does most damage, on rested land, newly reclaimed land, and land fertilized with nitrogenous fertilizers. The habit of resting land on alternate years, or of using nitrogenous fertilizers, seems to be responsible for the great spread of the disease on the Cooper River.

5. Rice blast has practically run its course in South Carolina, and probably will not spread further, *unless nitrogenous fertilizers are used, or resting practiced, on those lands that are annually producing poorer and poorer crops,* and already show the blast to a slight extent. Such land must be treated with great care; it must not be rested under any circumstances; if fertilizing is necessary to make a crop, non-nitrogenous fertilizers should be used, of which marl and particularly lime are recommended. Land that has so far not been fertilized or rested, or if so only at rare intervals, may be safely regarded as not subject to blast.

6. The disease is perfectly controlled by spraying, but spraying is not practicable with this crop.

7. There are so far no varieties of rice known to be immune to blast. Variety tests and selections for immunity, have so far failed.

8. The results of fertilizing experiments to date indicate that lime and marl produce as good growth of rice as nitrogenous fertilizers; that they do not predispose the rice to blast, but instead, exert a retarding effect on the disease. There are good possibilities in the use of lime and marl in combination with phosphoric acid and potash; but many practical details as to time and method of application remain to be worked out.

9. Of rice diseases other than blast (exclusive of insect troubles, of which no account is made in this bulletin), only smut and the so-called "rust" are serious, and both are now perfectly under control in South Carolina.

THE VALUE OF INDIVIDUAL EXPERIMENT.

It is evident that the only hope of preventing the occurrence or recurrence of rice blast lies in the use of alkali fertilizers—lime or marl, or, when more practicable, the avoidance of any resting or fertilizing process. The blast will not yield to the ordinary methods employed in the treatment of most plant diseases. But fertilizing irrigated rice land is a far more complex problem than fertilizing upland, and many details must be worked out by the individual planter. In the further solution of this problem, too much stress cannot be laid upon the value of experiments by individuals. If every man on whose plantation rice blast occurs would set aside two or three acres of land for special experiment, carrying out thereon some of the suggestions in this bulletin, and keeping careful and complete notes on all the work, most valuable results might be expected. Many experiments cannot be carried out by the planter, because they call for too close, too careful and too much work right at the busiest seasons of planting or harvesting. But none of the methods suggested in this bulletin are complicated enough to require much additional time or attention, and the possibility of good results far outweighs the trouble involved. It is only in this way that the question of what constitutes the best water treatment of land subject to blast can be solved at all. And in all other lines, the experiments which are being continued by State and National Government should be supplemented in this way.

A Preliminary Report on the Blast of Rice, With Notes on Other Rice Diseases.

INTRODUCTION.

This bulletin is the outgrowth of a co-operative arrangement between the South Carolina Experiment Station and the Bureau of Plant Industry of the United States Department of Agriculture, dating from May, 1904, under which the writer, as botanist of the South Carolina Station and collaborator of the Bureau of Plant Industry, has made studies of the diseases of rice, particularly in South Carolina, in both field and laboratory.

It is usual, in studying any plant disease with reference to preventive or remedial measures, to first ascertain definitely the exact cause of the disease; and then apply methods of prevention or cure in accordance with this knowledge. On account of the great urgency of the case, the writer reversed this more usual order, hoping to gain time thereby; since the determination of the exact cause of this disease was bound to be time-consuming, and moreover called for facilities which the writer did not have at the outset of his work. In consequence, the field conditions, and the circumstances of occurrence and distribution of the disease have been carefully studied, and the key to its control apparently discovered; although the cause and nature of the disease must yet be conclusively determined before further progress can be looked for.

The work has presented many difficulties not met with in the study of most plant diseases. In the first place, the difficulties under which the planters themselves labor, in making their annual hegira away from malaria to pine lands or city, and after that the long daily journeys by road or rail to and from the plantations, can hardly be realized unless experienced. Minute observation of any diseased field crop is not easy; but when it must be made in from two to four feet of water, on mud bottom with the temperature and fauna of the tropics, the difficulties are increased.

Furthermore, the peculiar agricultural methods employed in

rice growing, which make it easily the most unique staple crop grown in America, are no slight problem in themselves. Coupled with this there is immense variation in the nature of the rice land; and partly in consequence of this, partly for other reasons, a greater lack of uniformity in the methods of work of different planters than the writer has ever observed in the case of any other crop. Under these circumstances, it is not surprising that, with a disease presenting as varied an appearance as the blast, no two planters could be found, at the beginning of these studies, who gave the same account of it, its nature, appearance, or occurrence. Finally, the entire work on the problem had to be built newly from the ground up. There is no body of knowledge, already worked over, regarding rice diseases in this or any other country; this paper covers the first extended work on the subject done in America. On the matter of rice soils, their condition and treatment, no data were to be found, with the exception of the brief paper by Whitney (1893)* Questions of application of fertilizers to rice lands, the best method, time, amount, and the relation to water treatment, became in the course of the investigations matters of prime importance; but, aside from the limited experience of a few planters in the use of fishscrap and other nitrogeneous fertilizers, absolutely no data of local application were to be had on the subject.

It has become evident that the solution of the rice blast problem is to be found along the line of soil treatment and the use of certain fertilizers which will maintain the fertility of the land without predisposing the rice to blast, as in the case when nitrogenous fertilizers are used. Under these circumstances the absence of a body of practical knowledge and experience in fertilizing the rice lands is particularly unfortunate. All the details of application of fertilizers or fertilizing methods will have to be worked out anew; the problem is absolutely different from fertilizing upland unirrigated soil.

The problem of the control of rice blast is, then, as will be shown, a problem of pure agriculture, and not of pathology; and it involves the whole question of the continued fertility of the rice lands. Hence, further work on this disease will be

*Years in parenthesis refer to the list of publications cited, page 48.

divided into two lines; first, continued experiments with fertilizing and other methods of soil treatment, with reference to preventing the appearance of blast on land of reduced fertility, and if possible, causing its reduction or disappearance where it has already appeared (the latter a much more difficult matter): and second, technical and greenhouse experiments to determine the exact nature of the disease, with the hope of finding other modes of attack besides soil treatment. As hitherto, the work will be done by the S. C. Experiment Station in co-operation with the Bureau of Plant Industry of the U. S. Department of Agriculture.

Being only a preliminary bulletin, detail is sacrificed to brevity in the following pages, and many conclusions are stated while the details of the experiments upon which they are based are intentionally omitted. Finally, it must be remembered that the conclusions themselves are tentative, and subject to revision in later publications.

HISTORY OF OCCURRENCE.

It is impossible to say how long the disease of rice known as "blast" or "rotten-neck" has been present in South Carolina. A search through the remarkably complete and scholarly proceedings in the archives of the Agricultural Society of South Carolina and other similar bodies would doubtless shed much light on this question, as upon many features of ante-bellum agriculture. Such a search, however, has not been made by the writer, since, although of profound interest, there is nothing to indicate that results of a practical nature could be reached by such investigation. But it is safe to say that in all probability the disease has been in the State for many years, although not in sufficient amount to be an economic problem until the late nineties, when as will be shown later, agricultural conditions became such as to favor the disease. The earliest printed record of the disease that the writer has found is a letter by Col. John Screven (see Howard, 1882, page 136), in which Col. Screven describes what is unmistakably blast as occurring in appreciable amount at Proctors, on the Savannah River, as early as 1880.

Mr. W. F. Colcock has stated that he distinctly recalls what

was unmistakably this disease in a small experimental patch of rice which was cultivated by Mr. Olney Harleston at Bose's, on the East Branch of the Cooper River, and kept for a number of years in a highly fertilized condition. This was as early as 1878 and the disease reappeared on this patch year after year.

Not until as late as 1895 does the disease appear to have attracted much attention. This, however, does not necessarily mean that it may not have done serious damage before this time; on account of its obscure nature, it was difficult to recognize it as a distinct disease. The writer has been informed by many planters, that for several years they did not recognize the blast as a distinct disease. They did not perceive that the crop was materially damaged until, in the handling at harvest time, its light weight became evident; while in threshing, a large proportion of the grain blew out with the chaff, and in the milling a large per cent. of the grains went to flour. Unquestionably even at the present time, the disease has not been recognized on many plantations, where it has occurred in too small quantity or in too mild form to be clearly seen by a person riding a horse on the banks. The loss in such cases is naturally attributed to a "light crop." It is moreover confused with a number of other troubles (see page 37).

GEOGRAPHICAL DISTRIBUTION.

Rice blast occurs most extensively on the Cooper River, and has done its greatest damage there. It occurs on the Combahee and Edisto Rivers to an extent which is threatening but not yet serious except on limited tracts of land. The writer also has specimens from every other river in South Carolina where rice is grown; but except on the rivers mentioned, only scattering cases of blast have been observed, not enough to cause material damage. There is reason to believe that on the Savannah River there has been serious loss in the past, but that the disease was not recognized.

On upland rice the disease is probably distributed generally throughout the State, wherever upland rice is grown. The writer has specimens from Oconee County, as well as from localities nearer the coast.

The disease has also been reported from Louisiana and Texas. Apparently it has already caused serious loss in the latter State about Beaumont and Houston: but, as was the case in South Carolina, it is not always being recognized as a distinct disease. It is in this locality that further serious developments of blast are to be looked for, rather than on the South Atlantic coast; since in the latter locality the disease has probably run its course, provided more land is not made susceptible to it by fertilizing or resting.

So far as the writer has been able to determine to date, rice blast is confined to North America. While in some particulars it resembles the *carolo* or *brusone* of Italian writers (cf. Ferraris, 1903), it does not appear to be the same disease.

DESCRIPTION OF THE DISEASE.

Under whatever form rice blast appears, the characteristic feature is certain distinct lesions at one or more joints. Beginning as a very small spot on the sheath-node (the thickened turgid bright-green ring at the base of every leaf-sheath, just above the true joint of the stem), the tissue gradually dies until the joint is partially or entirely cut through. In consequence the parts of the plant above the affected joint die by degrees. This cutting off may take place at any joint above water (rarely below) and at any stage from just before the head is shot out until the grain is mature. The grain may thus be completely filled out, or not filled out at all. According to the weather conditions and the length of time that the dead top of the stalk is subject to the action of the weather, it may appear bleached, blackened, discolored in various ways or hardly altered at all. In the majority of cases, it is darkened rather than bleached. It will thus be seen that the diseased plants present the most varied appearance—more varied than is the case with any other plant disease known to the writer. This often makes the diagnosis of the disease a very difficult matter.

In about 70 per cent. of all cases observed the lowest joint on the rachis (*i. e.*, the first joint on the "neck" or "wire") was affected, in addition to one or more lower joints, and in conseqence the heads were broken off at this point. This phenomenon has given rise to a popular and expressive name for the

disease: "rotten-neck." This name, however, is not always applicable, for the following reasons: (1) The head does not break at this point if the lesion is at a lower joint. (2) If the head is very light, *i. e.,* the grains not filled at all in consequence of an early attack of the disease, it usually does not break off in any case. (3) No matter how badly Kiushu rice may be blasted at the neck, it very rarely breaks there. This is undoubtedly due to the great toughness and rigidity of Kiushu straw as compared with other varieties. It is unusual to find the neck affected without one or more of the lower joints being also diseased. But when this is found, it is usually not in a single stalk, but on all the plants within some given area. In other words, the occurrence of blast exclusively on the neck seems to bear some definite relation to locality.

It is evident from what precedes that the blasted rice plants present the most varied appearance above the affected joint. Below this point the plant is normal, so far as has been determined by the most careful comparative studies of diseased and normal plants. As is the case when the stalk is cut, sprouts are quickly formed below the diseased joint, and grow rapidly; the writer has seen several plants in which these sprouts, developing in an early case of blast, matured heads of grain late in the season.

A detailed account of these lesions at the joints is reserved for later publication; but the following naked-eye characters may be given here. If the lesion is below the neck, the first sign of the disease is one or more very minute spots, which appear on the sheath-node, directly above a joint. At first appearing merely water-soaked and sunken, these spots next become slightly discolored, brownish and almost black; a brownish coloration spreads up the sheath, usually for not more than an inch, but rarely for 3 or 4 inches; also downward, involving the whole joint, but seldom more than one-fourth to half an inch below the joint. At the same time the spot itself becomes more sunken, as though the tissue beneath were being eaten away, and extends laterally, girdling the stem; the different spots at the same joint become confluent; the skin breaks, and the open wound resulting may appear black or green or brown from the growth of various organisms on the dead tis-

sue. When the lesion is on the neck a slightly different appearance results, due to the harder tissue of this joint, which has no leaf-sheath and tender sheath-node. The same coloration appears and spreads up and down the stem in the same way, but the skin does not break unless the whole head snaps off at this point, nor does the spot appear soft, sunken or water-soaked at any stage. A miscroscopical examination of the neck shortly after the appearance of the spot reveals the presence of the spores of a certain fungus, not as yet positively identified. After the head dies these spores may develop over the greater part of the rhachis and even on the husk of the grains. This fungus also grows over the lower joints when the lesions are there; but are not as extensively present as on the neck. Occasionally, particularly in a late attack, the joints of the small branches of the head are attacked, instead of or in addition to the neck or lower joints of the main stem.

Similar lesions, followed by the same color changes and by the development of the same fungus, occur at the ligule, *i. e.*, the point where the leaf joins the sheath, and not infrequently cause the leaf to break off at this point. And finally, such lesions may occur at any point on the plant where it has been wounded; and may be produced artificially, as will be shown later.

THE CAUSE OF THE DISEASE.

As already indicated, detailed microscopical and inoculation experiments have not yet been made to determine conclusively the exact cause of the disease. All observations up to the present time, however, indicate that the lesions at the joints are caused by definite parasitic plant organisms working at these points. A more detailed statement at this time would be premature.

THE DIRECT CAUSES OF LOSS FROM BLAST.

Blast does its damage by arresting the development of grain. It may do this at any stage. If the blast attacks before the grain begins to fill out, the heads so attacked are of course a total loss, and the grain is not worth cutting. If cut, the grain blows out in threshing. The blast may, however, attack at any later stage; and the grain be stopped at any stage of its develop-

ment. The less developed it is, the less flint there is in the grain, and the greater the per cent. of it that goes to flour in milling, or is fanned out in threshing. Whatever the stage of development, the grain is light in weight as compared with healthy grain. Since all grains in the rice head do not develop simultaneously, there is much greater variation in the size and weight of the grains than is the case with healthy rice. On the whole there has probably been as much financial loss from a deficient quality of rice as from actual loss in quantity.

In a large proportion of instances the head snaps off at the neck, either while still standing, or during the processes of harvesting. Since it is the heaviest heads that have the greatest tendency to do this—that is, those in which a late attack of the disease has weakened the neck, but allowed the grain to become nearly mature, it follows that this may be a serious source of loss. The writer has seen fields harvested in which at least a third of the heads had snapped off in cutting and tying and were left on the ground. Kiushu rice, apparently owing to its tough straw, does not do this to any extent.

It will thus be seen that the actual loss from an attack of blast varies widely according to circumstances. Other things being equal, the younger the head when the disease appears, the greater the loss. The more rapid the progress of the disease after it appeared, the greater the loss. There is greater loss when the attack is on the neck than when on a lower joint; since in the latter case the disease progresses more slowly and there is much less loss from the breaking off of the head.

From this discussion, and from the description of the disease, it is evident that the per cent. of blast in a field (*i. e.*, per cent. of stalks diseased) gives no indication of what the yield may be, nor what will be the quality and consequent value of the grain. 100 per cent. of the stalks in a field may be diseased, and yet the crop be damaged only 10 or 15 per cent.; while on the other hand 10 per cent. of diseased stalks, if the disease strikes while the grain is in barrel, or progresses with unusual rapidity, may mean a 10 per cent. loss. It should be remembered, in reading the following pages, that per cent. of blast and per cent. of loss are not the same.

FINANCIAL LOSSES FROM RICE BLAST.

It is difficult to state in even approximate terms what the actual loss has been in South Carolina from this disease. In March, 1904, the rice committee of the Agricultural Society estimated the loss up to that time to be "very nearly one million dollars;" a conservative estimate at the present time would place the loss not below one and one-fourth millions. Of course not only the direct loss of grain is to be taken into account, but also the depreciation in land values, and other general effects resulting from the reduction of crops, abandonment of land and uncertainty as to the future of the industry in given localities. No account is taken of upland rice in this estimate.

What the loss has been in North Carolina in irrigated rice, and what the loss in both States in upland rice, it is impossible to estimate; the data on hand being too scattering and unreliable.

BLAST IN UPLAND RICE.

There can be no reasonable doubt that blast has caused on the whole as much financial loss on upland as on irrigated rice. The South Carolina Experiment Station was first advised by Mr. L. S. Connor of the occurrence of the disease near Orangeburg, S. C., as early as 1896, and apparently it had been prevalent there for at least ten years. This locality was visited in 1899 by Prof. P. H. Rolfs, and specimens collected by him at that time. Apparently the disease was widespread throughout South Carolina and extended into North Carolina; there is evidence of its occurrence for many successive years about Goldsboro, N. C.

No experiments have been made on upland rice by the writer. It is not known whether the conditions of occurrence and spread of blast are the same as on irrigated rice. The appearance of the diseased plants is identical, however, and the course of the disease the same.

No work has been done by either of the State Experiment Stations, or by the U. S. Department of Agriculture on the diseases of upland rice; and under the present commercial conditions, it would not be worth while to do any. But ten and twenty years ago, upland rice was a profitable crop in these

two States; and its enormous decline in acreage is in many localities due quite as much to this disease as to low price of the product. It is doubtful, however, whether many planters have recognized this fact, on account of the obscure nature and variable appearance of the disease. (See, also, Anderson, 1899, p. 4-5).

BLAST ON PLANTS OTHER THAN RICE.

As it is a well known fact that certain plant diseases are distributed by wild plants which have the same disease, a most careful search has been kept up for this disease on the wild plants in and about the rice fields. So far, the disease has been found only on a very few plants of the "cat-tail" (*Panicum crusgalli* L.); and it seems improbable that the disease can either originate or spread from this source. Further studies of the life history of the fungus associated with the disease may, however, reveal other hosts.

TYPICAL CASES OF BLAST.

The following examples are not the worst that could be obtained by any means, but have been selected rather because they illustrate intermediate conditions, and are therefore more representative. From notes in hand further examples might be indefinitely elaborated; but they would not throw more light on the subject than these.

I. NEWPORT (COMBAHEE RIVER).

Dawson's Field is a portion of the Newport Plantation, situated on the east bank of the Combahee River, about six miles from Green Pond. The plantation is managed by Mr. W. F. Colcock (P. O. address McPhersonville, S. C.). This field, consisting of 128 acres, is very peaty soil—the most typical "bay" land on the plantation. It was taken up in the spring of 1893 and planted with Gold rice. For three years previous to this time the land had rested, most of the time under water; and for many years prior to this had been planted irregularly in patches by negroes. The seed planted in 1893 produced a fine, heavy crop, with no signs of blast. Unfortunately, all of this, after being cut, was lost in the great storm of that year.

During the whole of 1894, the field was rested under reserve water. By the spring of 1895, the land was perfectly clean, *i. e.*, free from grass and weeds; it was plowed, harrowed, and planted with Gold seed; a magnificent crop resulted, which, however, blasted at an early stage and almost completely—worse than in any subsequent year. In 1896 Honduras seed was planted; a very heavy crop resulted, estimated at 75 bushels per acre, but blasted so that only 65 bushels per acre were harvested. From this time on Gold rice was planted every year. In 1897, a magnificent crop resulted, which harvested 76 bushels to the acre; with only a very little scattering blast. In 1898, the crop was estimated at 60 bushels to the acre; there was scattering blast all over the field; this crop was, however, lost in the storm of that year. From 1898 to the present year, the crop has been growing gradually less luxuriant, and the blast has probably decreased slightly. In 1904, the crop averaged 49 bushels to the acre; about 60 per cent. of the heads (exclusive of the rice on the experiment plots), were more or less blasted. In 1905, only one square of this field was planted; volunteer rice sprang up over the remainder of the watered portion of the field, and was blasted, but not quite so badly as the planted rice, which harvested somewhat less than 13 bushels per acre. The remainder of the field was rested dry.

Dawson's was the only part of the plantation where blast appeared, up to 1900. In the summer of that year, a few blasted heads were observed in Miles' Swamp, a field of 82 acres. This field was planted for many years before the war; but after the war was not used until 1893, when the myrtle was cleared and the field put under cultivation. In 1901 the blast appeared on the margins and in scattered portions of the field; worse in the lightest bay land. In 1902 the field was fertilized with 200 lbs. of high grade fertilizer (5-5-5); no stretch water was used, but the land was dry cultivated, until the harvest flow; the crop blasted badly. In 1903 the field blasted very seriously; the crop averaged only 26 bushels to the acre, although appearances promised a heavy yield. In 1904 no fertilizer was used; the crop blasted in spots, say 10 per cent. of all heads; 28 bushels to the acre harvested. In 1905, this entire field was rested dry.

Newport Swamp, the largest field of this plantation, has been under continuous cultivation for 40 years. For some years the crop has lightened somewhat, and to counteract this, fish-scrap and other nitrogenous fertilizers have been added, 200 lbs. to the acre each year since 1897. In 1903 scattering heads of blast could be observed; somewhat more in 1904; in 1905 spots of blasted rice could be seen in the squares where guano and fish-scrap had been applied; not yet in quantity enough to cause serious loss, but still an alarming increase over the previous year. Newport Swamp consists mostly of clay or more properly, alluvial mud land; but in the center there is some bay land, and this is where the blast has, for the most part, appeared.

II. MULBERRY (Cooper River, West Branch).

This plantation is situated on the West Branch of the Cooper River, about four miles from Oakley. Mr. John C. Porcher (P. O. address, Oakley Depot, S. C.), the present manager, began planting this plantation in 1897. Rice had been planted the year before; but the trunks were leaky and the whole plantation in bad condition. An excellent crop resulted in 1897; there was no blast. In 1898 the crop was "light." In 1899 fish-scrap was applied to the land—200 lbs. in March, before planting, and 200 lbs. more in June, before hoeing. A luxuriant crop resulted, which to all appearances would have made 60 bushels to the acre; but it blasted 80 per cent. Only an average of 10 bushels of rice to the acre was produced, and this was floury and of very poor quality. This was the first appearance of blast on this plantation, so far as Mr. Porcher knows. In 1900 a part of the plantation was rested under water; the remainder made a good crop; no blast was observed; but as the water in the river became salt the rice could not be watered and so the crop was lost. In 1901 the rice on the land that was rested in 1900 blasted; the remainder made a good crop. Up to this time, Gold rice had been planted exclusively; but in 1902, 100 acres were planted to Honduras rice. As in 1900, the river was salt, and all the Gold rice dried up; but the Honduras, which is less sensitive to drought, made 25 bushels to the acre and was only slightly blasted. In

1903 one-half of the plantation was rested under water; of the remainder, half was planted with Honduras rice, and half with Gold rice. The former did not blast at all; twenty acres of the latter, situated in a low spot, blasted almost completely. In 1904 the portion of the plantation rested in 1903 was planted entirely to Honduras rice. On the average, 95 per cent. of the stalks of this were blasted; but since the disease took effect late the actual total loss was not over 20 per cent. On account of the low price of rice in 1904, the blast, and the continual and increasing damage from salt water, rice growing was abandoned on this plantation in 1905.

III. CREIGHTON (Pon Pon River).

This plantation is situated on the west bank of the Pon Pon (Edisto) River, about four miles below Jacksonboro, and is owned and managed by Mr. W. E. Haskell, Jr. Gold rice has been planted exclusively since 1895 (except Kiushu as a June crop). As stated elsewhere, this plantation has suffered seriously in the past from "rusted" rice, but this is now entirely controlled by yearly applications of kainit. The total financial loss from blast on this plantation has been insignificant, for the reason that it has appeared on only a limited area, and as resting is not practiced on this plantation nor are any fertilizers except kainit used, it has not spread. It was first noticed in 1899 on a square of new land. (In this same year it was also first reported from other plantations on this river, but always on new land). It has appeared every year since, on this square, but never to such an extent as to cause more than 20 per cent. loss. On three other squares the blast has since appeared in noticeable amount, not exceeding 5 per cent. of all heads; and in various other squares scattering heads of blast could be found in 1904 and 1905.

A small patch of about 3½ acres newly cleared in 1903, was first planted in 1904 and about 35 per cent. of all heads blasted. In 1905 it was made the subject of the fertilizer experiments described on page 31; and about 20 per cent. of all heads blasted. About 10 bushels of rice per acre were gotten from this patch in 1904. About 30 bushels per acre in 1905. This

patch is the lightest bay land as well as one of the most poorly drained spots on the plantation.

CONDITIONS OF SPREAD OF BLAST.

An important problem in any plant disease, and one of increasing importance as our knowledge of plant diseases increases, is to determine the means by which the disease habitually spreads and the circumstances that favor its spread. The investigations of the past two years have revealed only a portion of the facts desired in this case. The disease occurs—that is, scattering heads of blast can be found—on every river in the State. But it has spread to a disastrous extent only in a few places; and many plantations can be found where it has not appeared at all; at least, where the most careful search fails to reveal a single blasted head.

Whether the disease shall attack any given stalk or not appears to depend upon (1) whether the parasitic organism, whatever it is, can gain access to the plant and ingress to its tissues; and (2) whether the condition of the plant is such that it will succumb readily to the attack, or resist it, so that in the latter case either the lesions do not appear at all, or else, if they appear, progress so slowly that they do but little harm. This conclusion is based largely on the results of inoculation experiments made in the field. In these experiments it has been found impossible to artificially produce the disease in a plant without first wounding it. This fact, coupled with what is known of the work of insects in distributing other plant diseases, and observations on the prevalence of certain insects about the rice at the time the inoculation apparently takes place, has led to the belief that insects transmit the disease and inoculate the plant with it. Observations on this point have been, and are still being made, by Prof. C. E. Chambliss of the S. C. Experiment Station, and will be published by him later.

So far not the slightest connection between the disease and weather conditions has been detected. More extended observations might, of course, reveal some such correspondence.

Luxuriance in itself does not mean that a plant is especially subject to blast; the disease can often be observed attacking the poorest and smallest plants, while the best plants are unaf-

fected. There is, however, some evidence that shading the lower parts of the plant, whether by dense foliage or close planting, greatly hastens the progress of the disease when the lesions are on the lower joints.

There is, up to the present time, no evidence that blast can be transmitted by seed. The general experience of various planters in the use of seed from healthy and blasted fields seems to confirm this view. Five hundred rice seeds, personally selected by the writer from partially blasted heads, and planted in pots and in various localities free from blast, developed no signs of blast; although thirty of the plants developing from this seed, taken at random, all developed blast when inoculated by direct contact of the previously wounded surface with the lesions of diseased plants; showing, apparently, that these plants were in condition to take the disease, providing the source of infection was present.

The view is occasionally expressed, that the increasing prevalence of blast is due to denegeration of native seed stock. This view is of course not tenable, when it is remembered how seriously Kiushu rice blasts, and that 76 newly introduced varieties, all from other countries, blasted in 1905.

A very characteristic feature of the disease is its sudden appearance, as if the infection took place all at one time. After this primary infection further spread of the disease from head to head and plant to plant appears to take place only to a very limited extent. The following experiment was made with reference to this point. In one field in which the blast suddenly appeared on August 8, 1904, 500 stalks were tagged on August 9 and 10 which were, so far as could be determined by naked-eye observation, absolutely free from the disease. Of the number, 452 were still perfectly sound when examined on September 2, just before being harvested. In another field, 300 stalks were tagged in the same way on August 16, and when examined on September 10, 267 of them were sound. It is, of course, highly possible, that of the 81 diseased stalks, some may have actually been diseased when first examined, since a microscopical examination could not be made at that time.

Only one distinct case of infection later than the original infection has been noted. See page 36.

It is impossible to prognosticate the course of the disease on any plantation. It often recurs on a limited area year after year without infecting adjacent squares. It does not recur regularly, but often skips a year in a given place in the most inexplicable way.

RELATION OF BLAST TO SOIL CONDITIONS.

Out of all the chaos of facts and fancies that presented themselves at the beginning of these studies one fact soon became evident: that some conditions in the substratum—either soil or water—exerted a profound effect upon the occurrence and severity of the disease. That one of these conditions is the presence or absence of nitrogen seems to be settled by the fertilizer experiments; what the others are must remain a matter for further investigation.

The great spread of the disease in recent years is due to the practice of resting portions of the land under water on alternate years; which results almost invariably in a magnificent crop, and which would be the best practice conceivable if it did not predispose the rice to blast. Since fertilizing annually with fish-scrap and other nitrogenous fertilizers produces the same blasting effect as resting, it has been assumed that the effect in both cases is due to nitrogen; only further experiment can determine the validity of this theory.

A study of the experience on all plantations shows that newly reclaimed land, when near land subject to blast, blasts as badly or worse than rested land. This might be expected, according to the theory expressed above. It is also a general experience that blast occurs more seriously on light peaty soil (bay land) than on clay or typical alluvial soil; there are, however, examples of alluvial land, and particularly clay land, that have blasted quite as badly as bay land.

INOCULATION STUDIES.

The method pursued was as follows: the plant to be inoculated was wounded, usually at the sheath-node, by scarifying a small area with a rough-edged knife. Then a scalpel was

plunged into a lesion of a diseased plant, withdrawn and rubbed on the wounded surface; the whole surface sprayed with water from an atomizer. In some cases the inoculations were made by simply pricking the lesion of the diseased plant and pricking the healthy plant immediately with the same needle, afterwards spraying with an atomizer. No marked differences resulted from the above variations in method. Sterile instruments were used, but aside from this no sterile precautions were taken at any time. Nearly all of the field inoculations were made between 10 A. M. and noon; a few were made in the late afternoon; no difference in results was noted. Check plants were scarified or pricked with a sterile knife or needle, and sprayed from an atomizer; in other words, they were treated exactly like the inoculated plants, except that they were not inoculated.

On account of the characteristic presence of fungus spores on the neck and adjacent tissues, that particular fungus was suspected of being the cause of the disease; and in order to settle the question, pure cultures of the fungus were obtained (with some difficulty), and used in inoculating healthy plants. Later, pure cultures of two bacterial organisms of almost constant occurrence in the interior of the diseased tissue were made, and used for the same purpose. With the pure cultures of these three organisms over two thousand inoculations have been made, to date, upon living rice plants, all in the field, at various stages, in very diverse localities, and employing various methods of inoculation. Without being more specific, it is sufficient to say that such a very small number of inoculated plants have developed symptoms of blast that the results of inoculations with pure cultures to date must be set down as negative. Just what this result signifies will be settled by further investigation.

On the other hand, not the slightest difficulty has been experieced, from the first, in producing blast in healthy plants, by inoculating them directly from the lesions of diseased plants. The plant to be inoculated must first be wounded, however; there is not the slightest evidencc to date that a plant can be infected through the uninjured epidermis. Apparently, the plant can be inoculated at any stage of its growth after the head is in barrel, but not before. Inoculations made on the

sheath-nodes produce lesions indistinguishable from those of the naturally blasted plants; but inoculations at any other point on the stem or leaves can apparently produce some slight effect. Inoculations in places other than the sheath-node appear to occur occasionally in nature.

Over three thousand direct inoculations from diseased plants have been made, under the most varied conditions. Out of this number, no cases have been observed in which some of the introduced organisms did not make some slight growth in the wounded tissue; but, in the case of rice growing in certain places, this growth did not seem to keep pace with the healing processes of the plant, and hence the disease did not develop. The inoculation experiments confirmed the field observations regarding the dependence of the disease upon some conditions in the substratum. Upon certain squares which had not become blasted, although surrounded with blast for years, it was found impossible to produce the disease by inoculation. Upon squares where the blast had already appeared naturally, it was easy to produce the disease by inoculation. These inoculations were checked very carefully by using two sets of check stalks; first, an equal number of healthy stalks which were wounded in the same way as the inoculated stalks, but not inoculated; second, an equal number of healthy stalks which were simply tagged for reference, without being either wounded or brought into contact with the lesions or material from the lesions of diseased plants. Of the latter set, not a single one developed the disease; of the former, less than 2 per cent.; of the inoculated stalks, more than 99 per cent.

Inoculations made in isolated localities, where the disease was not present naturally, gave varying results, but always very uniform in a given place. In every case the inoculation seemed to take effect at first; but in many cases the lesions did not become more than one mm. in diameter, while in still other cases they girdled the stem completely.

The results of inoculations of plants grown in pots, and of plants on fertilized plots of land are discussed on pages 33 and 29.

The following conclusions may be deduced from the inoculation experiments. These conclusions, however, have not yet

been tested by exactly controlled greenhouse experiments, and so must be regarded as to a great extent only tentative.

In order that rice blast may be produced the following conditions must be present: a. A source of infection. This is, ultimately, a diseased plant. b. A means of transmission of infecting material to the healthy plant. c. A means of wounding the surface of the healthy plant so that the infecting material gains entrance. d. A condition of susceptibility on the part of the healthy plant.

If any one of these conditions is lacking, the disease does not appear. How the disease, or the organisms producing the disease, live over from year to year, is yet to be determined. That insects are what actually furnish the means of transmission and inoculation seems probable, but is far from settled. Soil conditions, of which the presence of nitrogen is one, seem to determine the degree of susceptibility of the plant; there may be still other factors.

METHODS OF CONTROL.

I. WATER TREATMENT.

The results of observations and experience in regard to the relation of blast to water treatment are entirely contradictory. On many plantations it has seemed to be the most poorly drained squares that blasted most seriously; but so many low and poorly drained spots have been found free from blast, and so many high, well drained areas subject to it, that no general statement can be deduced. As has been said, the disease occurs frequently and typically on upland rice, where no water at all is used in cultivation. Moreover, the diseased plants themselves show none of the symptoms of "drowned out" or root asphyxiated plants. Yet none of these facts warrant us in drawing any final conclusion.

In Bulletin 41 of the S. C. Experiment Station, Mr. John C. Porcher described his method of water treatment with reference to the blast. This method consists essentially in keeping the rice practically dry in its later stages of growth. There is no doubt that Mr. Porcher achieved considerable success on his own plantation in carrying out his method. But the experience

of other planters who have tried the method is contradictory; some considering that using a minimum amount of water in the harvest flow, or withdrawing the water just as the head shoots out, distinctly reduces the blast; while others claim that such procedure has no effect whatever.

If a plantation subject to blast could be found which had dikes so located that different squares could be flooded separately, the value of this method, and indeed the whole question of relation of water to rice blast, as well as certain cultural problems connected with the water supply, could be settled by definite comparative experiments. But no plantation is known to the writer in which there is a sufficient number of fields that can be separately flooded, and the cost of constructing the necessary dikes on an ordinary plantation is prohibitive. It is, therefore, doubtful if such an experiment will ever be made; yet this is the way in which this aspect of the problem ought to be settled.

Whether the use of reserve water favors the spread of blast more than the use of river water is not positively known. There is a prevailing opinion among many planters that reserve water distinctly predisposes the rice to blast. No definite experiments concerning this point have been made.

There is a prevailing idea that the bad effects of resting land under water may be obviated by resting it dry instead. Fortunately this experiment is being made on a fairly large scale by Mr. W. F. Colcock and some others, and by the end of this coming rice season the results will be apparent. No experiment has yet been made to determine the effect of combining dry resting with growing a leguminous crop. Cow-peas have been grown to a limited extent on resting rice land on the Savannah River; but not on land that is positively known to be subject to blast.

2. Treatment with Fertilizers.

As has been stated, newly reclaimed land, land rested under water, and land fertilized with nitrogenous fertilizers are all particularly subject to blast; the writer has never seen a case of blast on old, continuously cropped, and unfertilized land. Evidently, then, the planter whose land is decreasing in fertility is forced either to continue to raise lighter and lighter crops;

or if he has recourse to fertilizing and resting, he must face the almost certain danger of losing his crop from blast.

The important problem, then, is to discover how to maintain the fertility of the land without producing blast. Experiments have accordingly been undertaken to find a fertilizer which would have as stimulating an effect on the rice plant as nitrate of soda or fish-scrap, without predisposing the plant to blast. The following experiments were conducted on land already badly blasted for several years. It was not realized until late in the work that much more decisive results could have been obtained on land not yet blasted, but requiring fertilizers in order to keep the productiveness up to standard. Experiments will be made on such land during the coming year.

It is furthermore probable that better results are to be obtained by applying the fertilizers before planting, instead of at hoeing time; but up to this year it has been impossible to arrange for experiments in time to apply the fertilizers in March and early April.

It will be seen from this brief discussion that the problem of fertilizing for rice blast is threefold: 1st, how to maintain fertility without producing blast, on land not yet blasted; 2d, how to control the disease on land already blasted for one or more years; 3d, how to control it on newly reclaimed land. The first phase is, in the present stage of affairs, by far the most important; the third, relatively unimportant. The experiments to date really apply with accuracy only to the second phase of the problem.

Experiments in 1904.

On the plantation of Mr. J. St. Clair White, on the East Branch of the Cooper River, on land subject to blast, one-fourth acre adjacent plots, with checks, were fertilized with the stated amounts of the following substances. Notes were taken on the growth through the summer; the rice from the various plots was threshed separately and gave yields as follows:

Plot.	Yield of plot.		Equivalent per acre to	
Check plot	13½	bushels	54	bushels
Nitrate of soda, 50 lbs.	14¼	"	57	"
Calcined marl, 384 lbs.	15½	"	62	"
Nitrate of soda, 50 lbs.; acid phosphate, 150 lbs.; kainit, 100 lbs.	15	"	60	"
Acid phosphate, 150 lbs.	13⅛	"	52½	"
Lee's agricultural lime, 330 lbs.	9¾	"	39	"
Lime, 348 lbs.	13¼	"	53	"
Check plot	9¼	"	37	"
Kainit, 100 lbs.	12½	"	50	"
Lime, 348 lbs.; magnesium sulphate, 25 lbs.; iron sulphate, 12½ lbs.	12	"	48	"
Check plot	15	"	60	"
Magnesium sulphate, 25 lbs.	10¼	"	41	"
Iron sulphate, 12½ lbs.	11½	"	46	"
⅛ acre check	7½	"	60	"
1-32 acre lime, 87½ lbs.	2	"	64	"
1-32 acre lime, 174½ lbs.	1¾	"	56	"
1-32 acre lime, 436 lbs.	2⅛	"	68	"
1-32 acre lime, 872 lbs.	2¾	"	88	"

The above quarter-acre plot was subdivided and fertilized at the suggestion of Prof. M. B. Hardin, of the S. C. Experiment Station.

All of these fertilizers were applied between the rows and hoed in on June 16, 21, and 22; on July 12 water was put on and remained on until the crop was harvested. It will be noticed that the highest yield was from lime applied in excessive quantities. The lime was applied so thickly that it was feared that the young rice would be killed by it; on the contrary, the rice with the greatest amount of lime throve most vigorously, was tallest, stoutest, greenest, and produced the heaviest yield. It was also slightly later in ripening than the rest. It will further be noted that a comparison of the check plots shows great divergence in yield. This is an unfortunate feature of fertilizer experiments on irrigated rice land; and seems to be due less to natural differences in the soil than to the effect of the

water in causing the diffusion of the fertilizer. Without exception it has been observed that the check plots show the effect of the adjacent fertilized plots in a way never to be seen on unirrigated land. There are, however, greater local differences in the quality of the rice land than is usually to be found in upland soil. From this, and other experiments, it has become evident that in order to obtain the best results on rice land, no plots of less than one acre should be used; and these should be isolated by ditches if possible.

With reference to the effect of fertilizer treatment on the blast, the results of observation of the growing crop seem to give more accurate results than determining the yield: unless extraordinary care is taken to consider the quality as well as quantity of the seed. In the above experiment this was not done: the yield given is of unfanned rice. The total amount, 181 bushels, when fanned, gave 130 bushels of clean rice; but more chaff and light grain may have come from some plots than from others, which fact makes the results to this extent unreliable.

Observations of these plots taken in the field at several stages of growth brought out the following facts: The rice on the two 1-32 acre plots, with the heaviest amounts of lime, was slightly wilted and retarded in growth for several days after the application of the lime; but very quickly this effect disappeared, and the plants became by far the best in the field. At harvest time the rice on these two plots averaged two to three feet higher than the average rice in the field. The plots fertilized with complete fertilizer, and with nitrate of soda, showed brighter color and stimulated growth as soon as the water was turned on; but this effect gradually disappeared. On the plot fertilized with acid phosphate alone, the coffee weed (*Sesban macrocarpa* Muhl.) was enormously stimulated, growing high above the rice and making the plot conspicuous from a distance. The relative luxuriance of the other plots is fairly well indicated by their yield as given.

On the unfertilized part of the field about 10 per cent. of all stalks were to some extent blasted. This was equally true of all the fertilized plots, except those fertilized with nitrate of soda, complete fertilizer and excessive amounts of lime. In

the two former 20 to 25 per cent. of the heads were blasted, half of these completely so. On the four 1-32 acre plots of lime, and on the nearest part of the adjacent check plots, there was less than 5 per cent. of blast, and that of a type that developed very slowly. If the entire field had blasted more seriously, as it was expected to do, the results would undoubtedly have been more clear cut. As it was, the results showed that lime in large amounts greatly stimulates the growth of rice and makes the plant distinctly less susceptible to the blast when attacked.

On Mulberry plantation, on the West Branch of the Cooper River, the above experiments were duplicated, with the exception of the 1-32 acre plots of lime with check. The place chosen was selected by Mr. Porcher as the one most likely to blast. The fertilizers were applied in June, and hoed in, as in the previous case; 18 days elapsed before water was put on, and much less water was used through the summer than is customary. The results were fairly clear-cut. On surrounding unfertilized land 95 per cent. of the stalks were blasted; but as the grain was nearly mature before the disease appeared, the actual loss was not more than 20 per cent. The two plots containing lime (which were equally luxuriant), and the plots of marl and Lee's agricultural lime were much less blasted than the surrounding plots—that is, quite as many stalks were affected, but the lesions remained of small size, and did not girdle the stalk. This was in striking contrast to the plots with nitrate of soda and complete fertilizer, where it was difficult to find any stalks at all that were not blasted seriously. The difference in this respect between these and the surrounding plots was very noticeable. While the growth on these plots was very luxuriant, it was hardly up to the standard of any of the lime plots. The rice fertilized with acid phosphate alone was blasted as much as the average unfertilized rice, but no more; and the heads were much larger and heavier. No difference could be detected between the other plots and the average rice outside of the fertilized area. All of the plots were harvested and stacked separately. The following plots made the largest stacks, in order of size: lime, and lime with magnesium sulphate and iron sulphate, about equal; complete fertilizer; cal-

cined marl; Lee's agricultural lime; nitrate of soda. Between the remaining stacks there were only slight differences. The stacks were to be threshed separately, to determine the yield of grain; but unfortunately they were blown over in a severe windstorm and so scattered and commingled that it was impossible to distinguish any except the lime, marl, nitrate of soda, and acid phosphate.

These yielded 14, 12, 4 and 12 bushels of clean (fanned) rice, respectively, *i. e.*, at the rate of 56, 48, 16 and 48 bushels to the acre.

The following inoculation experiments were made by the methods described on page 21; 200 stalks growing on the plot fertilized with lime were selected, ten days after the blast had appeared in the plot, upon which there were no signs of blast lesions. 100 of these, taken at random, were inoculated; the remaining one hundred were tagged as checks. All of the inoculated stalks developed lesions, but, like the natural lesions, they progressed slowly, and none of them girdled the stem, or became more than 3 mm. in diameter. Six of the check stalks became blasted.

An attempt was made to duplicate these inoculations on the plots fertilized with nitrate of soda and complete manure; but not enough healthy stalks could be found on those plots to make an experiment of any value. On an unfertilized bed some distance away the experiment was duplicated: 93 of the inoculated stalks developed lesions, of which 64 had completely girdled the stem at the end of 22 days. This was about the same proportion of complete blasting as in the naturally inoculated stalks in that immediate locality. Of the 100 check stalks four became blasted.

The same series of fertilizer experiments were also undertaken at Dawson's, on the Combahee River. Unfortunately, however, it was necessary, on account of the river becoming salt, to put on the harvest flow only two days after the fertilizers had been applied. On this account apparently, no results at all were obtained from this experiment: the differences between the different plots and the unfertilized land being too inconsiderable to note.

About two weeks before these fertilizers were put down, an experiment had been inaugurated on two acres of land nearby under the direction of Mr. Frank E. Taylor, of Charleston, S. C. On one acre was placed 1,250 lbs. of a fertilizer containing 100 lbs. phosphoric acid, 50 lbs. ammonia, 50 lbs. potash. On the other acre was placed 1,000 lbs. of a fertilizer containing 50 lbs. phosphoric acid, 50 lbs. ammonia, 50 lbs. potash. The source of potash was in both cases nitrate of potash; the sources of nitrogen, nitrate of potash, acid fish and blood; the source of phosphoric acid, acid phosphate made from S. C. rock. The experiment was made wholly with reference to yield; and in this respect would have been exceedingly successful had it not been for blast. Both plots grew luxuriantly, and produced immense heads; but were attacked by blast immediately after the heads shot out, and blasted almost completely. The line of demarkation in color between these plots and the adjacent rice was visible as far as the field could be seen. While of the surrounding rice 60 per cent. of all stalks were blasted, of which not more than one-fourth were girdled and completely killed; on these two plots hardly a stalk could be found that was not blasted completely. This blasting effect was still operative in 1905, as will be seen. This experiment thus confirmed in the strongest way the results of other experiments and the experience of many planters, that nitrogenous fertilizers predispose the rice plant to blast.

Mr. Taylor's conclusions from the results of this and other experiments are of interest. He "states that the result of the experiment has convinced him that the soil does not now, and will not for some years, need the addition of any nitrogen; that the amount of nitrogen contained in the soil is sufficiently ample to produce a luxuriant growth, and that on this deduction he is clearly of the opinion that the land should be fertilized heavily with phosphoric acid to produce the fruit, and heavily with potash to produce the stem. He is also of the decided opinion that the acidity in the land should be corrected before the application of any fertilizers, and believes that by broad-casting, say a thousand or more pounds of calcined marl to the acre, and turning this under after a crop has been harvested; and before preparation commences for another crop,

that the application of this calcined marl would to a large extent correct the acidity in the land. He argues that at such time as may be deemed best by each individual planter an application of fertilizers should be made on the land, of not less than 100 lbs. of phosphoric acid and 50 lbs. of pure potash to the acre. He is of the opinion that the best form of these two ingredients can be obtained by using high grade acid phosphate with potash, the potash to be derived from sulphate of potash and not from muriate of potash."

Experiments in 1905.

Upon seven acres of land at Bose's, selected by Mr. White as most likely to blast, the following fertilizers were applied. respectively: 200 lbs. muriate of potash, 1 ton lime, 2 tons lime, 600 lbs. raw phosphate rock, 200 lbs. sulphate of potash, 1 ton calcined marl, 600 lbs. acid phosphate, and 200 lbs. sulphate of potash. The fertilizers were put on June 12 and 13; the harvest flow June 27. The plots gave, respectively, the following yields in bushels of clean rice: 30½, 34, 23, 33, 31¼, 32¾, 38. This was not above the average yield of unfertilized land; nor were the variations greater than what occur naturally. There was very little blast. There was no evidence, either from yield or from inspection of the field at any time, that any of the fertilizers had the slightest effect.

The rice planted on the site of the 1904 experiments showed absolutely no effects from the fertilizers of the preceding year: with the exception of that on the site of the 1-32 acre plots. Here the rice seemed slightly retarded in the young growth; but after hoeing even this effect passed away.

At Creighton the small 3½ acre patch referred to on page 17 was fertilized as follows: on one acre, 1 ton of lime; on another acre, 1,600 lbs. calcined marl; on the third acre, 200 lbs. sulphate of potash; one-half acre left unfertilized. The yield from this entire patch in 1904 was 35 bushels; in 1905 it was 105 bushels. Inspection of the standing rice showed that 20 per cent. of all stalks were blasted. In the check plot and the sulphate of potash plot the blast had progressed most rapidly, doing perhaps 40 per cent. more damage than in the other plots. Between lime and marl there was no difference in

degree of blasting or luxuriance. On the whole, the effect of the fertilizers on this piece of rice was less than would have been expected. The fertilizers were applied June 6, and the harvest flow put on June 11.

At Dawson's six acres of fertilized land gave the following results:

Fertilizer.	Yield in bushels.	Weight in lbs. per bushel.
1 ton lime......................	11½	36
2 tons lime.....................	14	36
200 lbs sulphate of potash.......	14	35
200 lbs. muriate of potash.......	12	35
600 lbs. raw phosphate rock......	14½	37
1,600 lbs. calcined marl.........	17	35

One check plot of one acre gave a yield of 16 bushels, weight 35 lbs.; while 2 1-3 acres, unfertilized, lying beyond the influence of the fertilized plots, yielded only 19 bushels in all, or 8 1-7 bushels to the acre. From the entire 9 1-3 acres 150 bushels of chaff and light grain were fanned out.

Inspection of the plots at the time of cutting showed that the entire field was blasted, 90 per cent. of all stalks. Unlike the results in previous experiments, the lime plots were on the average as badly blasted as the rest; although much more luxuriant than the unfertilized rice. Careful examination, however, showed that this was due to the fact that a part of the lime plots were on the site of the experiments made by the Ashepoo Company in 1904; and this part was almost totally blasted. The residual effect of those experiments was equally obvious in the unplanted part of the field, the weeds and grass being much more luxuriant over the places where the nitrogenous fertilizers were applied in 1904. The only fertilizer which appeared to have exerted any noteworthy effect was calcined marl: this plot was distincly more luxuriant and less seriously blasted than the rest. These fertilizers were applied June 12, and the harvest flow put on July 3.

An analysis of all the results from fertilizer experiments to date shows that in every case there has been either (1) no effect from any of the fertilizers in a given experiment, or (2)

that the nitrogenous fertilizers strongly predisposed the rice to blast, while lime and marl exerted some retarding effect on the disease, and made the rice quite as luxuriant in growth as the nitrogenous fertilizer. Where any marked effect has been obtained, it was favorable to the use of lime and marl in fertilizing land subject to this disease.

But why all the fertilizers failed so completely to show any effect in some cases, must be a subject for further study. One would naturally conclude that it was due to flooding the land too soon after applying the fertilizers. This may or may not be the true reason. The coming year's experiments will show whether harrowing in the fertilizers in the spring will give more decisive results that applying them in June.

Pot Experiments.

In the summer of 1903, at Clemson College, Prof. Harmon Benton conducted a pot experiment with Gold rice, using soil from rice fields that had blasted seriously, and imitating the field irrigation as closely as possible. The same fertilizers were used as in the field experiments on page 26 (with the exception of Lee's agricultural lime, ferrous sulphate, and magnesium sulphate), and at the same rate per acre. All the pots grew well; but slaked lime gave by far the best results, and in direct proportion to the amounts used; the limed plants growing larger and heavier not only in weed but in head, and also growing a little more slowly than the others. None of the pots showed any blasted heads. This pot experiment was the basis from which the 1904 field experiments were made; and, as will be seen by comparison, the results were similar.

In 1905, pot experiments were made in the following way: Early in June, 48 rice plants which had sprouted naturally in a rice field known to be subject to blast were transplanted, with the soil immediately surrounding them, into as many large flower pots with holes in the bottom. The following fertilizers, at the given rate per acre, were then thoroughly mixed with the top layers of soil to the depth of six inches; and the pots were taken to a swamp several miles from any rice field and set in a few inches of water, so that the soil in the pots was kept dry on top. The pots were left in this condition for 22 days, then they were sunk in water, and remained flowed in

depths of water varying from ten inches to three feet, until the grain ripened. The water conditions were not ideal; nevertheless all the rice made as good growth, and some much better, than in the field from which the rice had been taken. The rice in the field became blasted, 80 per cent. of all stalks; but none of the rice in pots blasted, except what was blasted by inoculation. One-half of the stalks of every plant were left uninoculated, as checks on the inoculated stalks, and to show the results of the fertilizers. Each experiment was in duplicate. The average weight of the grain produced per stalk by the uninoculated stalks of the best pot of a pair was determined; the average of the poorest check pot is calculated as 100; others in proportion:

Fertilizer.	Equivalent per acre to	Proportionate yield.
Check		100
Nitrate of soda	200 lbs.	140
Calcined marl	1,400 "	185
Nitrate of soda	200 "	
Acid phosphate	600 "	180
Kainit	400 "	
Check		105
Acid phosphate	600 "	160
Slacked lime	1,400 "	200
Lee's agricultural lime	1,400 "	185
Check		115
Slaked lime	2,000 "	205
Slaked lime	4,000 "	220
Slaked lime	20,000 "	385
Check		110
Calcined marl	600 "	145
Calcined marl	2,000 "	180
Calcined marl	4,000 "	190
Check		120
Phosphate rock	600 "	165
Sulphate of potash	200 "	140
Muriate of potash	200 "	135
Magnesium sulphate	100 "	115
Check		120

It will be seen upon careful inspection that the above results correspond in a general way with the results of the field experiments, but are much more distinct and positive.

The inoculations, made by the methods given on page 21, also were the same in general results as those made in the field; but more clear-cut. All inoculations made in this way took effect, without exception. None of the checks became diseased. The pots containing nitrogen in any form became most seriously blasted, the disease progressing with great rapidity. The unfertilized plants were uniformly blasted, but not as seriously; while on the plants fertilized with lime and marl the lesions devoloped very slowly, the greater the amount of fertilizer the less the blast. Inoculations of stalks in each pot with pure cultures of each of the two organisms most constantly present in the lesions, gave only negative results.

No other pot experiments were made on account of lack of facilities for exact control.

3. Other Soil Treatment.

Whether the physical condition of the soil has any effect on the occurrence of the disease has not been experimentally determined. Nor is it known what effect upon the disease a different cultural system (*e. g.*, deeper plowing), might have, or any procedure that would modify the physical conditions and aeration of the soil.

4. Spraying.

Results to date show that if it were practicable to spray a rice field the whole problem would be solved. Several experiments made in 1904 on a very small number of plants showed that spraying with Bordeaux mixture (5-5-50) just before the head shot out prevented the appearance of the disease. In 1905, these experiments were repeated by carefully spraying ten small patches of rice in localities that were expected to blast. These patches were purposely made of fantastic shapes, in order to show the results more clearly. The spraying was done while the rice was still in barrel. The blast appeared on less than 1 per cent. of the sprayed stalks, in some patches not at all, while the surrounding rice was blasted from 15 to 100 per cent. The spraying was not repeated. In two patches, which were

kept under close observation until the rice was harvested, the disease appeared six weeks after spraying, affecting 40 per cent. of the stalks, but, of course, doing little damage at this stage. The surrounding rice had blasted, 90 per cent. of all stalks, four weeks before. This is the only case that the writer has observed of a second infection later than the primary one. No spraying mixtures other than that mentioned have been tried.

5. Securing Immune Plants.

There is at present in the United States no variety of rice that is immune to blast. Apparently it is safe to say that Gold rice is most sensitive to the disease, Kiushu next, Honduras least; but the degrees of susceptibility vary but little. The various white rices grown in South Carolina, both upland and irrigated, are at least as sensitive as Kiushu; and even wild, red, or "volunteer" rice is subject to the disease. 76 varieties of rice supplied by the Division of Seed and Plant Introduction of the United States Department of Agriculture, from various parts of the world, were tested in 1905 by planting in several places known to be subject to blast: without exception these were blasted too seriously to offer any hope; most varieties being blasted more than the native varieties.

The writer has not been able so far to find in the worst blasted fields any entire individual plants absolutely free from the disease; so there is no basis for selection for immunity. In 1904, 4,500 seeds were selected from various plants that seemed to have fewer stalks blasted than surrounding plants. These were planted in 1905, in various places most subject to blast; but the plants produced did not show the slightest tendency toward immunity, being all blasted quite as much as the surrounding plants that were not from select seed.

Experiments with varieties will be continued, although there seems to be but little hope of success.

There are or have been on the market certain strains of rice claimed to be immune to blast. So far experience has not sustained these claims; still the same claim is made every year for some so-called new variety. It is well for every planter who has land subject to blast to make a fair experiment by planting a small area with such supposedly immune seed. Only in this

way can the truth be arrived at. But no planter can afford to plant large areas with such seed unless it is known to be equal in quality with the standard commercial seed and not higher in price.

6. GENERAL SANITARY MEASURES.

Careful burning over of land and destruction of all debris, and such similar measures as are commonly used in combatting bacterial diseases of plants, for example, have not yet been tried for the control of blast. Experiments along this line will probably be made the coming season. From the nature of the case, there would seem to be little hope of success by such methods.

OTHER DISEASES OF RICE.

1. SMUT.

A serious smut of rice along the Sampit River was reported in 1899, by Anderson, and methods of treatment were devised, or applied from previous data, by him and Walker (Bul. 41, S. C. Exp. Sta.), and recommended by them to the planters wherever the disease might appear. These methods appear to have been efficient, for the smut did not spread beyond its original area; it has not been reported from any rice plantations since 1903, nor has the writer ever observed any. There can be no doubt that the disease was checked at its inception, and to Anderson and Walker must be given the credit of doing a most valuable piece of work for the State. Judging by the harm this smut did in its limited area, and the harm done by smut to other grains, the disease would in a few years have become as disastrous as blast.

2. "RUST."

This name is applied by different planters with a fair degree of consistency to a disease of wholly obscure and probably physiological origin and nature. It has been by some confused with blast, but is absolutely different. In 1897, it was first reported to the Department of Agriculture by Mr. W. E. Haskell, Jr., of Jacksonboro. It was reported to the S. C. Experiment Station in 1898, by Mr. Jno. B. Gregorie, of Yemassee.

On the plantations of these two gentlemen it caused serious loss, and has also been destructive on other plantations. This "rust" should not be confused with the true rusts of other grains, since no rust fungi (*Puccinia,* etc.) are associated with it. In this disease the leaves gradually die, beginning at the tips of the lower leaves; in late stages this may involve all of the leaves. Before dying, the green color of the leaves often appears intensified. After dying, the leaves may of course become darkened, bleached, or otherwise discolored by the action of the weather. Generally, and most typically, red spots or streaks appear on the leaves while still green. Various fungi, including a *Cercospora* of fairly constant occurrence, are found on the leaves. Certain spots also resemble those caused by bacteria in broom-corn and sorghum (cf. E. F. Smith, 1905, pl. 20). The rusted plants are usually dwarfed, sometimes conspiculously so over a large area of land. There are no distinct lesions on the stem. The head often fails to develop and is always small and light. The roots appear blackened when first pulled out of the ground; but this black color disappears upon exposure to the air for several hours. The roots are less developed than those of normal plants, and do not penetrate into the ground so far; the plants have a noticeably weak "hold" on the ground. Superficially the symptoms resemble those of root asphyxiation. Unlike blast, this disease appears to hold no definite relation in distribution to the substratum.

The writer has made over a hundred inoculations by direct contact with rusted leaves, and by pure cultures of the fungi found on the rust leaves, into healthy plants of various ages, growing in the most diverse situations. Plants growing in spots subject to the rust were used as well as those growing where the rust had never appeared. All inoculations were made in the field, *i. e.,* there were no greenhouse or pot inoculations. Without giving a detailed account, it is sufficient to say that all of the inoculations gave an absolutely negative result. There is thus not the slightest evidence to date that the disease is of parasitic origin. These negative results, coupled with the successful prevention of the disease by kainit, incline the writer to the view expressed above, viz: that the disease is physiological.

Mr. Haskell deserves great credit for having independently discovered how to control this "rust" on his own plantation. His method appears to be entirely efficient. He controls the disease by fertilizing; applying kainit, 400 lbs. to the acre. The kainit is put on in clay land in harrowing, before planting; in bay land, is broadcasted by hand before the harvest flow. No effect of the kainit is visible until after the water is on. Mr. Haskell has used kainit in this way every year since 1900. According to his experience in 1900, kainit is effective if applied even as late as when the rice is in barrel.

It is a curious fact that lower on the rivers, where the land is occasionally subject to salt water, kainit does not seem to have any effect on the rust. Whether potash in any other form would be effective in this case remains yet to be determined. So far as the writer knows, no experiments have been made with reference to this question.

Lime apparently has no preventive effect on this disease. Mr. Haskell applied it in 1897, in quantities of 60, 50 and 25 bushels to the acre, with no results so far as the rust was concerned.

A single experiment made by Mr. Haskell, in 1897, indicates that spreading straw thickly on the land and burning it over thoroughly might control the rust. In this one case the results were very good. Since, however, the application of kainit is cheaper and more practicable, the experiment with straw was not repeated.

This so-called "rust" appears to strikingly resemble the *brusone* as described by certain writers (cf. Brizi, 1905).

3. STERILE HEADS.

A disease of rice, so far nameless, has been reported from Texas, in which the glumes simply remain empty, the heads in consequence standing erect; while aside from this the plant is normal, so far as has been detected. This disease is said to occasionally cover considerable areas. Nothing is known regarding the nature of it. It has not been observed in the field by the writer, nor has it ever been reported from South Carolina. It is possibly the same disease as the *esterilidad* of South American writers.

4. DAMPING OFF.

When rice seed is planted in "open trench," *i. e.*, not covered with earth, but simply flowed with water, the seedling often dies after attaining a length of about half an inch. When seed is covered with soil in the more usual way, and then the water applied, the water is let off after about a week; in planting "open trench" the water may be left on. Hence, the latter method, although for the above and other reasons more uncertain in its results, is often used, as it saves work and water.

Seedlings dying under these conditions show, when examined, a progressive soft rot of the shoot: the roots are normal, so far as can be determined by eye and microscope. No fungi are present, only bacteria. No prolonged cultures nor inoculation tests of these bacteria have been made. It is entirely possible that this rot is saprophytic.

When rice is covered it is also subject at a slightly later stage than the preceding, to damping off of a different type. In this, *Rhizoctonia,* as well as other fungi, and bacteria, are present in definite lesions above the surface of the ground. Whether this is similar to the disease described by Duggar and Stewart (1901) in dry land plants has not been positively determined. These two types of damping off described are distinguished from one another by many planters. The loss occasioned by them is in the long run very considerable. In this connection it should be remembered that rice is also destroyed at this stage by insects: not every loss of seedling rice is to be attributed to damping off.

5. SPOTTED BLIGHT OR BIRD EYE.

Occasionally heads of rice are found in which the grains are covered with small black spots, and have filled out incompletely or not at all. The plant is otherwise normal. A microscopical examination of the grains shows them to be covered with the spores of a fungus, *Macrosporium sp.,* which appears to be the cause of the disease. The fungus has been found to grow in pure culture very readily, but no inoculation tests of its pathogenic power have been made. This disease is at present of insignificant importance; usually occurring only on scattered individual heads, but occasionally destroying the heads of rice

in spots of from ten to two hundred feet in diameter. It thus might easily become serious. It is widely distributed, having been collected by the writer from every river in South Carolina where rice is grown; and also reported from North Carolina, Georgia, Alabama, Louisiana and Texas.

INSECT TROUBLES.

Several of these strongly simulate blast, and are even now confused with the blast by many planters. Howard (1882) has described them in some detail. No extended mention of them will be made in this bulletin, since a bulletin on the rice insects is to be issued by Prof. C. E. Chambliss, of the S. C. Experiment Station, in collaboration with the U. S. Department of Agriculture.

EFFECTS OF GROWTHS OF ALGAE.

Algae—green masses of slime, on the surface or submerged—develop rapidly and to an enormous extent in the water of rice fields and ditches; particularly is this the case when reserve water rather than river water is used in irrigation. Not infrequently the growth of algae in the sprout or stretch water is so dense that when the water is withdrawn the algae form a dense layer on the surface of the ground, which bends down the young rice and retards or prevents its growth. This phenomenon is often spoken of as "tying down." Also, the great mass of algae clogs the ditches and retards the flow of the water, and so prevents prompt drainage of the land. While some of the vegetable growth that stops up the ditches consists of aquatic flowering plants, the bulk consists of algae; and the labor of ditch cleaning would be reduced 90 per cent. if the algae growth could be killed or prevented from forming.

Although the conditions in a rice field are very different from those in a reservoir, it seems reasonable to suppose that the method devised and applied by Moore and Kellerman (1904, 1905) for destroying algae in reservoir waters might be also applicable, with slight modification, to the rice field conditions. According to a brief experiment conducted by the writer, the rice plant is entirely resistant to the action of copper sulphate in quantities far in excess of what would be expected to kill

the algae. Specific directions will be given to any planter who wishes to experiment with copper sulphate for this purpose.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge his great obligations to the planters with whom he has worked, especially the gentlemen whose names have been mentioned in this bulletin, and the Chairman and members of the Rice Committee of the Agricultural Society of South Carolina. The thanks of the writer, and, indeed, of all interested in the solution of this problem, are due Mr. S. G. Stoney, for seed rice and fertilizers, and to Mr. G. Walter McIver, for fertilizers, used in many of the experiments described in this bulletin.

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